

Yield and mechanical properties of veneer from *Brachystegia nigerica*

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Abstract: In an effort to find suitable wood from natural forest to meet the demand for veneer products, the yield and tensile strength of veneers produced from *Brachystegia nigerica* were investigated. Two trees of *B. nigerica* were separately selected from 10 different natural forest zones while two logs were obtained from each tree. The logs were debarked and steamed in a vat prior to rotary peeling and slicing for veneer production. The optimum steam temperature was determined by considering different temperatures: 50°C, 60°C, 70°C, 80°C and 90°C for 24 h. Thereafter, optimum steam time was determined at the optimum temperature by considering durations of 24, 48, 72 and 96 h. The average taper of 0.75 mm per 1.0 m length was recorded for *B. nigerica*, indicating that the logs were reasonably cylindrical; thereby its logs are good for the production of veneer. The yield ranged from 44% to 61% with an average of 52% of the log input. The tensile strength of the veneer was tested perpendicular to grain and both peeled and sliced veneers had the highest tensile strength between 70°C and 90°C, suggesting that softening of wood polymers, especially lignin, is between 70°C and 90°C. The optimum temperature and time for veneer production are 70°C and 48 h, respectively. Commercial production of veneer from *B. nigerica* is feasible based on the yield and mechanical properties of the obtained veneer, thereby encouraging the expansion of the scope of its utilization.

Keywords: veneer; *Brachystegia nigerica*; yield; tensile strength; optimum steam temperature; optimum steam time

Introduction

There is aggressive deforestation in the Nigerian natural forests

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without the corresponding replacement of the removed forests. The demand for wood products continues to increase, thereby causing the depletion of the forests in almost all parts of Nigeria. There are about 560 tree species known as commercial timber in Nigerian forests (Lucas 1979). Unfortunately, only a few of these are used in the existing wood processing industries and about 14 of them are actually used for veneer production. This is because veneer logs must fulfil certain stringent technological conditions relating to log form and wood quality. Apart from the physical properties which include straightness of the bole and minimal taper, wood species should preferably be naturally resistant to degrading agents such as decay and insect infestation. In addition, it should not contain fragile knots and heart rots. Despite the apparent possession of the required properties for solid lumber production, *B. nigerica* has not been listed among the favoured veneer species (Lucas and Olufemi 2001). It is presently being exploited and used for saw logs.

The study of wood quality for purpose of finding possible uses for a tree species is not a new approach. Kärki and Vainikainen (2004) and Uusitalo (1994) conducted wood quality studies on aspen (*Populus tremula*) logs and pine stands, respectively, for sawn-wood production. These same wood species are also known to be good veneer species and therefore, it is very important to conduct research on the properties of *B. nigerica* for possible use as veneer production source. Note that the production of quality veneer involves some special considerations like debarking and steaming the log prior to peeling. The purpose of heat treatment or steaming is to reduce residual stresses and enhance even distribution of moisture within the logs (Nogi et al. 2001). It also improves wood color and controls cracking of the surface of the log. However, excessive heat treatment ruptured the pit membranes, which simultaneously increased the permeability of wood and decreased the moisture gradient within the log (Ando et al. 1996). Based on this fact, understanding the appropriate steaming temperature and duration would enhance better quality and yield of veneers from *B. nigerica*.

It is known that solid sawn timbers perform well in commonly used engineered components such as trusses and pre-fabricated I-joists (Brashaw et al. 2001). Engineered composite materials whose base is veneer represents one of the fastest growing seg-

ments of the wood products industry (Ross et al. 2004). These products become more advantageous when used in laminated veneer lumber (LVL) whose demand is high in new industrial construction because it can be made to large billets from veneer sheets that are bonded together with an adhesive system. The billets can be produced to a specified thickness and cut into desired width. One of the most significant technical advantages of LVL is the adaptability of its design to specific performance characteristics (Ross et al. 2004). This advantage enables it to be used in variety of products which include commodity structural components, wind turbine blades and other specialty products. This study aimed at investigating the yield and mechanical properties of veneer produced from *B. nigerica* in order to expand and enhance the scope of its utilization.

Materials and methods

The identification of *B. nigerica* was carried out in ten selected zones in the rainforest belt of Nigeria where the species is reported to be in abundant (Kio et al. 1985). These zones are located in seven States across the southwest and southeast of Nigeria: Akwa Ibom state (Lower Enyong forest reserve; 7.93°N, 5.05°E), Anambra state (Awka forest reserve; 7.07°N, 6.21°E), Cross River state (Ukpon forest reserve; 8.33°N, 6.09°E and Afi forest reserve; 8.71°N, 5.96°E), Edo state (Usonigbe forest reserve; 5.23°N, 6.31°E and Amahor forest reserves), Ogun state (Omo forest reserve; 4.37°N, 6.85°E), Ondo state (Oluwa forest reserve; 4.69°N, 6.85°E and Aponmu forest reserves; 5.04°N, 7.32°E), and Oyo state (Adekunle forest reserve; 3.84°N, 7.16°E). In each of the forest zones, one forest area was randomly selected and two trees were felled as representative of the whole zone. The forests wherein the test logs were extracted are listed in Table 1. The felled trees were converted to test logs (length = 1.3 m, diameter = 0.59–0.61 m). Two test logs were taken from each tree to the mill. The diameters were measured inside bark at both ends of the log and the lengths of the test logs were recorded; the average diameter and length were then used to estimate the total wood volume in each log. The logs (bolts) were then debarked and grouped into two sets: one set was converted into veneers using rotary peeling method while the second set was converted using slicing method (those for slicing were cut into flitches). The bolts and the flitches were then steamed in a vat for 24 h at different temperatures (50°C, 60°C, 70°C, 80°C and 90°C) with the goal of investigating the optimum steam temperature. Further study was conducted to determine the optimum steaming time (duration). The steaming times used were 24, 48, 72 and 96 h at the determined optimum steam temperature, respectively. All veneers coming out including full sheets, strips and fishtails were marked to avoid mix up and added together to calculate the yield (based on the volume of the initial bolt and flitch). The veneers were dried to 10% moisture content using oven-dry method as specified in ASTM (2007). Test samples were cut from full sheet veneers to determine the strength and quality (uniformity of thickness) of both peeled and sliced veneers.

Table 1. Average taper of measured *Brachystegia nigerica*

Zone	Average taper (mm)
Oluwa - Ondo	0.77
Aponmu - Ondo	0.61
Omo - Ogun	0.82
Adekunle - Oyo	0.70
Usonigbe - Edo	0.74
Amahor - Edo	0.83
Awka - Anambra	0.72
Ukpon - Cross River	0.78
Lower Enyong - Akwa Ibom	0.73
Afi - Cross River	0.83
Mean	0.75 ± 0.01

Statistical analysis

The data collected for all test parameters were analyzed using analysis of variance (ANOVA) at the significance level of $p < 0.05$ and Duncan's New Multiple range Test (DNMRT) was used as a follow up analysis to separate the means.

Results and discussion

The average taper of 0.75 mm per 1.0 m length was recorded for *B. nigerica* (Table 1). The practical significance of this taper value is that the logs of *B. nigerica* collected from the ten zones were reasonably cylindrical. Considering the poor properties of logs from natural forests and the suitability of available logs in the wood market, the log form of *B. nigerica* is good for the production of veneer. During the reconnaissance, the trees that were selected for felling were not characterized by low branching as none of them was found to branch before 10 m length of bole.

The total volumes (yield) of peeled and sliced veneers produced from *B. nigerica* (when logs were steamed for 24 h) are presented in Tables 2. The lowest and highest yields for peeled veneers are found at 50°C (14%) and 90°C (46%), respectively. For sliced veneers, lowest and highest yields for peeled veneers are found at 50°C (13%) and 70°C (49%), respectively. Generally, the yield of veneer was improved with increase in steam temperature for duration of 24 h. The yields obtained for temperatures of 70°C, 80°C and 90°C were not statistically different. Therefore, the optimum steam temperature is 70°C because the additional cost of energy needed to steam up to 80°C and 90°C would cause higher cost of veneer production cost. The yields at 50°C for both rotary and slicing techniques were significantly low because the core diameter that was dropout was large (about 0.38 m compared with the initial diameter of about 0.59–0.61 m; more than 50% was rejected as waste). This is consistent with the study conducted by Steinhagen et al. (1989) on appropriate temperature and duration of heating logs of Grand fir and Douglas fir. There are some substantial revenue losses in under-heating of

logs because large core dropouts constitute a waste of wood raw material (Steinhagen et al. 1989). At the optimum temperature (70°C), 72 h of steaming gave the highest yield of 48% (peeled veneers) while the highest yield of 50% is found at 96 h of steaming. However, the optimum steam duration was 48 h (Table 3). Steaming *B. nigerica* logs prior to rotary or slicing peeling above 48 h can cause unnecessary increased energy cost.

Table 2. Veneer yield of *Brachystegia nigerica* at different steaming temperatures for 24 h

Heating temperature (°C)	Yield (%)	
	Peeled veneer	Sliced veneer
50	14±2.1	13±1.4
60	27±1.6	29±1.5
70	45±1.6	49±1.0
80	45±1.3	48±1.1
90	46±1.5	48±0.9

Table 3. Veneer yield of *Brachystegia nigerica* at different steaming times at 70°C

Heating time (h)	Yield (%)	
	Peeled veneer	Sliced veneer
24	38±0.8b	38±0.5b
48	47±1.2a	49±0.9a
72	48±1.0a	49±1.3a
96	47±0.6a	50±0.8a

Means with different letters in the column are significantly different ($p<0.05$)

Mechanical properties

The quality of veneer is generally affected by a number of factors which include: the quality of logs, the condition of logs during storage, heat treatments given to the logs prior to cutting, set up and the operation of the peeler or slicer. The factors that were checked in this study are the strength and uniformity of thickness. The tensile strength perpendicular to grain of the veneer was tested as it is the only quantifiable test for measuring the tightness or looseness of veneer. For both peeled and sliced veneers, the effect of the heating temperature on the tensile strength was statistically significant; the steamed veneers had the highest tensile strength between 70°C and 90°C (Table 4). Steaming of logs at 50°C and 60°C produced veneers with very weak tensile strength. This suggests that the logs were not well softened at these temperatures. However, between 70°C and 90°C steam temperatures, there were no significant differences in the tensile strength of the veneers produced except for peeled technique at 90°C. From these results, it could be deduced that softening of wood polymers especially lignin have been achieved. The softening temperature of any polymer is commonly known as glass transition temperature; a temperature at which polymer moves from glassy to rubbery state and vice versa. It has been reported that most plasticised (using plasticiser like water) woods have

their glass transition temperature at around 70–100°C (Furuta et al. 1998; Olsson and Salmen 1997; Chowdhury et al. 2010). Therefore, the softening temperature of *B. nigerica* is likely to be within the temperature ranges of 70–90°C. Its practical implication is that the knowledge of the softening temperature of wood prior to veneer production is essential to producing high tensile strength. In addition it is preferred to steam at 70°C because steaming at a higher temperature will incur more cost. The heating durations for both peeled and sliced veneers were statistically significant and when the strengths were compared, the peeled sliced veneers had the highest tensile strength when the logs were heated for 48 h (Table 5). Prolonged steaming at 70°C beyond 48 h produced weak tensile strength, suggesting the degradation effect of steaming logs at temperature near glass transition temperature for a longer.

Table 4. Tensile strength perpendicular to grain for veneer from *B. nigerica* at different temperatures for 24 h

Heating temperature (°C)	Tensile strength (N/mm ²)	
	Peeled veneer	Sliced veneer
50	0.66c	0.71b
60	0.90c	0.88b
70	1.29a	1.26a
80	1.23a	1.24a
90	1.18b	1.20a

Means with different letters in the column are significantly different ($p<0.05$)

Table 5. Tensile strength perpendicular to grain for veneer from *B. nigerica* at 70°C for different durations

Heating Time (h)	Tensile strength (N/mm ²)	
	Peeled veneer	Sliced veneer
24	0.74c	1.02c
48	1.45a	1.66a
72	1.26b	1.26b
96	1.15b	1.13c

Means with different letters in the column are significantly different ($p<0.05$)

It is desired that veneer thickness be uniform because variation in thickness will adversely affect the quality of drying as well as gluing operations. For the 2-mm nominal thickness, the range of variation was 0.17 mm for 20 rounds in samples measured (data not shown). This was too small to affect the overall drying results and therefore cannot affect the glue spread if it is to be used for plywood or in furniture overlay. The less variability in the veneer thickness may be due to the heat pre-conditioning.

Conclusion

In this study, the yield and tensile strength of veneers produced from *B. nigerica* were investigated. The logs of *B. nigerica* were reasonably cylindrical with average taper of 0.75 mm per 1.0 m length; hence its logs are suitable for the production of veneer.

The veneer yield ranged from 44% to 61% with an average of 52% of the initial volume of the log input. The optimum steam temperature at duration of 24 h was 70°C; however, the optimum steam time at 70°C was 48 h. Therefore, the maximum veneer yield for steaming *B. nigerica* log is obtained at 70°C for 48 h. Similarly, the veneer at the steam temperature (70°C) for a period of 48 h had the highest tensile strength irrespective of the veneer production techniques: rotary or slicing. Steaming below or above 70°C would not be economical because large quantity of wood waste (core dropout) and high cost of energy generation would be incurred.

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